Proceedings of the Iowa Academy of Science

Volume 33 | Annual Issue Article 37

1926

Anticlines of the State of Iowa

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ANTICLINES OF THE STATE OF IOWA

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Foreword

This paper was written because the author has felt the need of a report covering the anticlinal folds of the State of Iowa, together with a record of the drilling which has been done.

There is very little information available on this subject. The work done has been in connection with a study of the general geology of the State. No report dealing with the folds has been made except in Vol. 29 of the Iowa Geological Survey (Howell), which includes a brief review of the subject but tells nothing of the location, extent, or surface configuration of formations. There have been many instances where a resume of these structures would have saved time and energy and I have finally concluded that such a review has a place in the Geology of the State.

Most of this report has of necessity been gleaned from the volumes of the Iowa State Geological Survey, the publications of the Iowa Academy of Sciences, and the geologic bulletins of neighboring states. The best that the author has been able to do has been to give a brief outline of the location, dip and strike, axial trend, surface formation, and any record of drilling which has been done on the structure.

Information concerning many of the wells drilled for oil in this state can not be included here because it is not available. Any data of such nature has been included where it has been possible to get it.

There are many structures lying within the boundaries of the state which appear favorable for oil and gas accumulation, but so little is known concerning them that it is a presumption to say they are favorable or unfavorable. No work on these structures has been done, to my knowledge, which has concerned itself with the depth of the folding, "structural highs," drainage area, closure, etc. It is work that should be carefully done before drilling is undertaken.

There is displayed at the surface over the greater part of the state of Iowa a succession of the beds of the Paleozoic, ranging from the Cambrian to the Pennsylvanian with a small area of

Permian at Ft. Dodge. Farther to the west the Cretaceous overlies the greater part of northwestern and western Iowa. In the extreme northwestern corner of the state there is a small area of the Proterozoic. Each of the beds of the Paleozoic, with the exception of the Permian, appears at the surface in a long narrow belt, successively farther from the center of uplift which lies to the northeast in the Lake Superior district. (See Iowa Geological Map.) For this reason the anticlinal structures which are known to exist in the northeastern part of the state are not considered favorable for oil and gas accumulation. The beds which would be oil bearing are at the surface and are not thought to have retained the oil which may have been in them.

The general direction of the dip of the Iowa strata is toward the southwest. That statement represents approximately the total amount of knowledge concerning the structure of the Iowa formations. As Keyes has said in the Iowa Academy of Science Vol. 23, "Beyond the general assertion that the foundation rocks dip gently to the southwest, no further note is made of the local or broader tectonic characters." There are some very excellent discussions among the State geological reports concerning the Thurman-Wilson fault, and a map showing the location of some 16 structures in the state. (Howell, Iowa Geol. Surv., Vol. 29, Plate 4, 1920.)

In this report I have followed the division of the state into districts as made by Norton in his report on Ground Water, Vol. 21, Iowa Geological Survey (1910-11), discussing each area in regular order.

NORTHEASTERN IOWA

This division of the state comprises the eleven counties of Allamakee, Black Hawk, Bremer, Buchanan, Chickasaw, Clayton, Delaware, Dubuque, Fayette, Howard and Winneshiek. (Norton, Iowa Geol. Surv., Vol. 21, p. 279, 1910-11.) The record of drilling in this section of the state is meagre, but there are a few structures of sufficient size to warrant mention. The oil and gas possibilities of this district are of little interest as the formations which are the possible reservoirs are exposed at the surface.

Allamakee County — The Snymagil anticline is located in the northwestern part of Allamakee county. The oldest exposed bed is the Oneota limestone. The best exposure is in the south side of the valley of Bear Creek in the vicinity of the town of Quandahl. Calvin has the following to say in regard to this structure. "In section 35 of Makee township there is a series of exposures

of the contact of the Trenton and Saint Peter. These exposed layers show a steep inclination to the northeast. On the opposite side of the crest the strata are for a mile or two nearly level and then dip to the southwest at the rate of about 35 feet per mile." (Iowa Geol. Surv., Vol. 4, p. 86-87, 1894.) There are other minor folds noted on the flanks of the larger fold throughout the county. Calvin further states, "The main fold passes from the southeast to the northwest across Allamakee county. The anticlinal axis lies a short distance southwest of the town of Quandahl, section 25 Waterloo township." Howell (Iowa Geol. Surv., Vol. 25, Fig. 4, p. 53-54, 1914) cites a minor fold on the Sny-Magil anticline, whose crest dips toward the southwest. The crest of this fold passes through Iron Hill.

Norton in his report on Underground Water Resources of Iowa shows the northeastern Iowa structure in his geologic section (Iowa Geol. Surv., Vol. 21, Plate V, 1910-1911.) from McGregor to Mason City. This does not include the Snymagil structure. Water wells drilled in the vicinity of this structure penetrate the Jordan sandstone at shallow depths.

Winneshiek County — In Winneshiek county there are minor folds reported on the west flank of the Snymagil structure. The beds as a whole dip strongly to the west near the northeastern county line. The axis of the Snymagil anticline lies just across the line in Allamakee county.

In the northeastern part of Pleasant township a low anticline is reported by Calvin (Iowa Geol. Surv., Vol. 16, p. 77, 1905). "The axis extends northwesterly, passing through Sattre and Locust in the northeastern part of Pleasant township. The Saint Peter sandstone is the surface formation and passes northwestward through the central part of Glenwood township, includes the northeastern corner of Decorah, the eastern part of Canoe and Hesper, the central parts of Pleasant, and the northwestern part of Highland townships."

A well was drilled southeast of the town of Decorah in Decorah township in 1922-23 by the Decorah Pioneer Oil and Gas Co., a local concern. The drilling contract called for 3000 feet, but granite was struck long before that depth was reached. A showing of oil with much salt water was reported from this well. Whether, or not the well was located upon a structure is unknown to the writer. The surface beds are the Platteville-Decorah of the Ordovician.

Clayton County — One or more low anticlinal folds are reported by Leonard (Iowa Geol. Surv., Vol. 16, p. 289, 1905) from the

vicinity of Sny-Magil creek in Clayton township between McGregor and Clayton in Clayton county. The surface formation exposed in the creek bottom is the Oneota, the lower bed of the Ordovician.

Bremer County — In Bremer county three and one-half miles west of the town of Tripoli an exposure of the Niagara beds is brought to the surface by a local upwarp. Other exposures which seem to indicate structures lie southeast of Waverly, on Baskin Run, Sections 16 and 17, Township 91 N, Range 13 W and near the mouth of Quarter Section Run; Section 20, T. 91, N; R. 13, W., where the Niagara beds are again at the surface. The outcrop near Tripoli is aligned with the Oelwein-Fairbank anticline and is probably an extension of it (Norton, Iowa Geol. Surv., Vol. 16 p. 342, 1905). The outcrop of the Niagara near Waverly is known as the Waverly Anticline. (See also Norton, Iowa Geol. Surv., Vol. 27, Plate III, 1916).

The Geologic Section shown on Plate 7, Vol. 21, Iowa Geol. Surv. 1910-11 (Norton) shows the structure from Vinton to St. Ansgar and the anticline at Waverly is quite pronounced. (See also Geologic Map of Bremer county).

A well drilled for the Pioneer Oil Co., in 1903 by L. Wilson & Co. of Chicago was carried to a depth of 1,025 feet. This was near the town of Frederika. Whether or not the well was located on a structure is unknown, but from the geologic map it may have been on the flank of the extension of the Oelwein-Fairbank structure. The record of the strata is given on p. 321 of Vol. 21 Underground Water Resources of Iowa. (Norton, Iowa Geol. Surv., 1910-11).

A water well at the town of Waverly penetrates the flank of an anticline to a depth of 1720 feet. Record given in Iowa Geol. Surv., Vol. 21 p. 325, 1910-11. Of this fold Hager, D. S. (Oil and Gas Journal, March 1, 1923) says, "Another structure underlain by Ordovician rocks is an extensive fold which begins in Delaware county and extends northwestward across Buchanan into Bremer county. A possible structural "high" is indicated near the town of Tripoli, Bremer county, by an exposure of Niagaran dolomite, in an area elsewhere covered by Devonian rocks — the log of the deep well at Waverly, located probably to the west of the axis of the structure — wells drilled on the uplift would reach the Ordovician rocks at shallow depths, but the prospects are not encouraging."

According to the reports of Norton (Iowa Geol. Surv., Vol. 16, 1905) and Hager, D. S. (Oil and Gas. Jour. March 1, 1923) the

structure in Bremer county is a long and possibly continuous one from Delaware to Bremer counties. Howell (Iowa Geol. Surv., Vol. 29, Plate IV, 1920) shows on his map an anticlinal axis which strikes at right angles to the trend of the fold cited by the other two writers. It is prominent only in Bremer county.

It is the writer's belief that there is more than one structure in Bremer county. One of them is a continuation of the Oelwein-Fairbank fold, the other a minor fold on the southwestern flank of that fold, both of which have brought the Niagara to the surface.

Black Hawk County — In Black Hawk county Arey reports a low anticline which extends from the west side of the Cedar River at Waterloo to the south county line (Iowa Geol. Surv., Vol. 16, p. 447, 1905). The limestone of the Cedar Valley formation is at the surface. (See Iowa Geol. Surv., Vol. 21, p. 280, 1910-11).

Fayette County — In Fayette county Savage (Iowa Geol. Surv., Vol. 15, p. 499, 1904) reports the presence of a fold that brings the Niagara outcrop forty feet higher than the base of the Devonian. This outcrop lies two miles north of the town of Fairbank, Section 20, Oran township. This is the fold which Norton described as being aligned with the Bremer county folding (Iowa Geol. Surv., Vol. 16 p. 342, 1905).

Buchanan County — In Buchanan county Calvin reports the existence of a "steep anticlinal fold which has lifted the Niagara much above the position it normally would have occupied. This structure lies in the northeastern part of the county where a salient angle of the Niagara cuts a deep notch in the eastern edge of the Devonian." (Iowa Geol. Surv., Vol. 8, p. 220, 1897). Calvin further states that, "This is one of the most marked and extensive folds affecting the geological strata of Iowa which begins in Delaware county and extending across Buchanan passes into Bremer. . . . So far this fold has not been fully explored by the drill; but the deep well at Waverly is not very far from its axis." (Iowa Geol. Surv., Vol. 12, p. 27, 1901.)

Delaware County — The Buchanan county structure is reported as a continuation into Delaware county. It is noticeable in the center of Richland township. In both counties the Niagara is the surface formation. (Calvin, Iowa Geol. Surv., Vol. 8, p. 179, 1897.)

Dubuque County — In this county the Eagle Point anticline is a well exposed structure, cut by the Mississippi and exposed in the face of the bluffs along the river. The strike of the anticline is almost east and west, crossing Couler valley nearly at right angles.

(Calvin and Bain, Iowa Geol. Surv., Vol. 10, p. 478, 1899.) The structure takes its name from its good exposure at Eagle Point. The Saint Peter sandstone is the surface formation.

There are other minor folds in the county, one of which lies to the west of Spechts Ferry and has an east-west trend. Howells extends this structure into Clayton county, but no record of it is to be found in the report on Clayton county. (Howell, Iowa Geol. Surv., Vol. 29, Plate 4, 1920.) There is no record of any change of dip in the southwestern or south-central part of Clayton county nor in the northeastern part of Delaware county which would account for the fold shown on his map in the northwestern corner of Dubuque county.

The above listed structures represent all of the prominent folds in northeastern Iowa. There probably are small structures which have not been mapped and some of the larger ones given here may not be as extensive as assumed. However, the record of these anticlines may permit of some conclusions regarding the structure of this part of Iowa.

EAST-CENTRAL IOWA

The east-central area fronts on the Mississippi; it comprises the twelve counties of Benton, Cedar, Clinton, Iowa, Jackson, Johnson, Jones, Linn, Muscatine, Poweshiek, Scott and Tama.

Benton County — Savage (Iowa Geol. Surv., Vol. 15, p. 216, 1904) reports the occurrence of a narrow lobe of limestone, embracing the Spirifer pennatus beds, the strata of which form an arch, on either side of which the layers slope downward at an angle of about 45°. Other minor folds reported from Benton county by Savage bring the Spirifer pennatus beds to the surface. The largest fold reported lies in Section 22, southwest corner, Cedar Township where the Coggon beds are exposed. If this location is correct, the fold lies on the west side of the Cedar river. Howell (Iowa Geol. Surv., Vol. 29, Plate IV, 1920) shows a fold which extends from north of Vinton in a northeasterly direction across the county line into Buchanan county. This fold is not mentioned in the report on the county geology by Savage.

Norton's columnar sections in Benton county show no structures, but he reports the drilling of a well in search of oil by a Mr. C. Fee. The depth was reported to be between 2000 and 3000 feet. No location is given. (Iowa Geol. Surv., Vol. 21, p. 438, 1910-11.)

Linn County — There are two known structures in Linn county,

both reported by Norton (Iowa Geol. Surv., Vol. 4, pp. 129 and 139, 1895). The one lying in the eastern part of the county is known as the Viola anticline. It is a well defined structure, but the presence of the Le Claire beds which have the anamolous dip characteristic of the formation makes more difficult the definition of the structure. The surface beds are of Silurian age.

The other well defined structure is known as the Bertram anticline. It is a low fold which cuts across the valley of Big Creek in Linn and Bertram townships. The Pentamerus beds of the Silurian are exposed in the bottom of the creek valley. The trend of the axis is northwestward from Mt. Vernon. Norton states that, "This fold is a continuation of the deformation to which the presence of the Silurian in the east-central and southern parts of the county is due." (See also Iowa Geol. Surv., Vol. 6, p. 236, 1897.)

Jones County — No structures are reported from Jones county. A well was drilled at the edge of the town of Monticello in the valley of Kitty Creek during 1923 to a depth of 950 feet. The well was drilled by local capital. No structure is present at that place. The surface formation is Niagara.

Jackson County — "In Jackson county a low arch is reported as extending from Savanna in Illinois, in an east and west direction, to the east side of Section 30, Fairfield township, a distance of about 20 miles. The strata involved embrace the Maquoketa shale and the overlying beds of the Niagara limestone." (Savage, Iowa Geol. Surv., Vol. 16, p. 640, 1906.)

Clinton County — Norton reports that in 1907 the Texas Drilling Co. put down a well to a depth of 1,716 feet in the SW $\frac{1}{4}$ sec. 11, T. 82 N, R 3 E. This well penetrated the Cambrian. A cross section through the region is shown on the structure sheet. (Iowa Geol. Surv., Vol. 21, Plate XI, 1910-11. Also see page 495.) The section and well were located on the south flank of the structure noted under Jackson county. A record of the drilling is on page 496, Vol. 21, Iowa Geol. Surv., 1910-11.

Cedar County — In Cedar County Norton (Iowa Geol. Surv., Vol. 3, p. 182, 1893) reports an anticline or dome at the crossing of Rock Creek, the SE$\frac{1}{4}$ of SW$\frac{1}{4}$, Sec. 23, T 80 N, R 3 W. The beds of the Wapsipinicon stage of the Devonian are at the surface, overlying the Gower beds. Here again the anamolous dip of the Le Claire phase may be misleading and should be carefully checked.

Two miles west of Lowden in Cedar county the same author reports a low anticline in which the Anamosa beds of the Silurian are at the surface (Iowa Geol. Surv., Vol. 11, p. 317, 1900).

Muscatine County — At West Liberty and Wilton Norton (Iowa Geol. Surv., Vol. 21, Plate XV, 1910-11) shows the existence of a large fold trending northwest-southeast.

Norton later reported the existence of a pronounced anticline called the Stanwood Anticline. This fold has been recognized through drilling for water in the vicinity of Stanwood, Cedar County. The structure is shown in cross section on Plate XI, (Iowa Geol. Surv., Vol. 21, 1910-11).

SOUTHEASTERN IOWA

The southeastern district embraces the eleven counties of Davis, Des Moines, Henry, Jefferson, Keokuk, Lee, Louisa, Mahaska, Van Buren, Wapello and Washington.

Louisa County — There is some gas produced in Louisa county from the glacial drift. Enough is produced to light and heat a few homes. There are no known structures in the county. A prospect hole for gas was drilled one-half mile west of Letts, Iowa on the land of W. W. Wagner to a depth of 1,135 feet, with no results.

Keokuk County — There are three anticlines reported from Keokuk county by Bain (Iowa Geol. Surv., Vol. 5, p. 158, 1895). The Springvale, Manhattan, and a smaller unnamed structure. "The Springvale structure lies in Sections 26, 27 and 35, T. 75 N, R 13 W. The axial trend is northeast-southwest. There are two points where the Mississippian beds are brought to the surface — in Jackson township, and five miles southwest of Sigourney in sections 17, 18, 19 and 20, T 75 N, R 12 W."

The Manhattan anticline is located in Jackson township and has a northeast-southwest strike. The Augusta beds of the Mississippian are at the surface.

The Skunk River structure of McGee (Eleventh Annual Report, U. S. Geol. Surv., p. 336 et seq. 1893) is supposed to lie in this region, but all structures are reported to run at right angles to the strike of this supposed anticlinal. (See Bain, Iowa Geol. Surv., Vol. 4, p. 292, 1894).

A small structure is reported by Bain as lying about midway between the Springvale and Manhattan anticlines. This is not a well defined structure and should be carefully examined. The Augusta beds are at the surface.

Howell (Iowa Geol. Surv., Vol. 29, Plate 4, 1920) shows but one structure in Keokuk county, the strike of which is northeast-southwest and lying south and east of Sigourney.

Mahaska County — McGee reported the existence of the Des

Moines anticlinal and the Skunk River anticlinal (Eleventh Annual Report U. S. Geol. Surv.) Bain (Iowa Geol. Surv., Vol. 4, p. 348, 1894) states, "while no evidence can be found of a series of deformations running from northwest to southeast, there is some slight evidence of a series running at right angles to that direction. Owen (Rep't. of Geol. Surv. of Wis., Iowa and Minn., Ch. III., Philadelphia, 1852) as early as 1852 called attention to evidence of an, "anticlinal crossed by the Des Moines river near Bellefountaine. The greater part of the difference in elevation is due to erosion but . . . it is not improbable that a slight anticlinal is present." A similar phenomenon appears on the South Skunk near both the Roberts and McBride Mills. These deformations do not appear to be of great extent and in Mahaska county cannot be directly connected with one another. In Keokuk county to the east similar deformations have been noted and traced across the county."

Howell (Iowa Geol. Surv., Vol. 29, Plate IV., 1920) noted on his map an anticline in the northeastern part of Mahaska county having a northeast-southwest trend and extending into southeastern Jasper county.

There seems to be some dispute as to the location and trend of the structures in Mahaska county. Careful checking should be done before further work is undertaken.

The surface formation in each of the structures reported along the north and south Skunk rivers is the Saint Louis exposed in the bottom of the river valleys. Norton (Iowa Geol. Surv., Vol. 21, Plate XV, 1910-11) shows the existence of a large fold trending northwest-southeast.

Jefferson County — There are no recorded structures in this county. An oil well prospect was drilled near the east limits of the town of Fairfield by Mr. H. Pumphrey. It is reported to have reached the Saint Peter sandstone of the Ordovician.

Henry County — The geological map of Henry county indicates the presence of an anticlinal structure along the Skunk River in Jackson township which has brought the Keokuk beds of the Mississippian to the surface. Another such outcrop occurs near Lowell in Baltimore township. Savage (Iowa Geol. Surv., Vol. 12, p. 295-6, 1901) reports the outcropping of these beds, but gives no description except that the axes of the folds trend in an east-west direction (See Geological Map Henry County, Ia.).

Des Moines County — In Des Moines county the city of Burlington lies very near to the crest of a low fold known as the

Burlington anticline (Keyes, Iowa Geol. Surv., Vol. 3, p. 461, 1893). (See also Fig. 31 same volume.)

The Kinderhook formation is at the surface on this structure. What appears to be another structure is shown in the Skunk River section by Keyes (Iowa Geol. Surv., Vol. 3, p. 428, 1893). From this section the conclusion is drawn that a structure lies parallel to the Mississippi. Keyes states that this cross section is nearly transverse to the trend of the slight deformations which exist. (Iowa Geol. Surv., Vol. 3, p. 427, 1893, also Fig. 32.)

Lee County — In Lee county the Keokuk Syncline is the outstanding structural feature. There are minor undulations of the strata, reported by Keyes, which have had very little examination (Iowa Geol. Surv., Vol. 3, p. 364, 1893.) An oil well was drilled near Ft. Madison during the latter part of 1925 by Mr. H. J. Schroeder. A showing of oil was reported from this well in November. The reported depth is around 850 feet. Further information has not been made available.

Washington County — Norton's cross section (Iowa Geol. Surv., Vol. 21, Plate XIII, 1910-11) shows an anticlinal structure near Washington, Iowa.

Van Buren County — In Van Buren county the Bentonsport anticline is a pronounced fold. It takes its name from the town of Bentonsport which lies near the axis. "The strike is about N. 63 W; pitching quite abruptly to the west, but more gently to the east extending across Lee county reaching the Mississippi at Nauvoo, Ill., at which point it is scarcely perceptible." (Iowa Geol. Surv., Vol. 4, Plate VI, Fig. I, 1894.) Gordon in the same volume states that corrugations of a minor character, however, interrupt the general inclination. These minor corrugations may be structural highs on the flank of the major fold. At Keosauqua in Van Buren county private capital has drilled a well on "a small dome lying within the Keosauqua loop of the Des Moines River NE¼ Sec. 26, T 69 N, R 10 W. Oil was found at 874 feet in the beds near the top of the Silurian. The deeper beds have not been tested." (Quoted from a publication issued by the Keosauqua Commercial Club April 1925 and written by W. G. Osborn who located the well.) The oil is supposed to be from a stray sand similar to that producing in the Colmar field in Illinois. The surface formation is the Saint Louis. It is planned to deepen the drilling this year. Since this report was written the well was completed as a dry hole. Another well is now being drilled.

This completes the record of the known structures of the south-

eastern part of Iowa, and from the data at hand it is apparent that further work should be done throughout the region. At present the southern and southeastern part of the state must be regarded as favorable oil territory until proven otherwise. The Iowa Geological Survey in Vol. 25, page XIII of the administrative report discusses conditions in this section of the state. Where the geological maps of this section show the Mississippian beds through the overlying beds it may indicate, not folding, but erosion of the surface of the underlying Mississippian beds.

NORTH-CENTRAL IOWA

The north-central district comprises the eleven counties of Butler, Cerro Gordo, Floyd, Franklin, Hancock, Humbolt, Kossuth, Mitchell, Winnebago, Worth and Wright. That part of Iowa known as the north-central district contains so few outcrops of rock and such heavy deposits of drift that very little is known concerning the structure of the rocks. Some idea is obtained from wells in the eastern part. The only western well of depth is at Algona and it has no log. Norton (Iowa Geol. Surv., Vol. 21, p. 749, 1910) has the following to say regarding the north-central district, "The predominant dip of the Paleozoic strata is southward. In the northern part of the area the strata dip gently toward the east, the axis of the trough lying apparently in Floyd county. In Floyd and Butler counties a strong southwestward dip is evident. The gradient of the Saint Peter from Osage to Ft. Dodge is about 9.5 feet per mile and from Mason City south to Hampton is nearly 20 feet per mile."

CENTRAL IOWA

The central district comprises twelve counties situated in central Iowa — Boone, Dallas, Greene, Grundy, Guthrie, Hamilton, Hardin, Jasper, Marshall, Polk, Story and Webster.

Hardin County — At Iowa Falls in Hardin county there is a pronounced arching of the strata. This has long been known as the Iowa Falls Flexure (Beyer, Iowa Geol. Surv., Vol. 10, p. 267, 1899). On the geologic map of Hardin county there appears to be another structure or a continuation of the above mentioned one, in Ellis, Tipton and Pleasant townships where the Kinderhook beds are again at the surface. No mention of a structure at this point is made in Beyer's report. The Iowa Falls Flexure is well exposed along the wall of the river at the town of Iowa Falls. The deep well at Iowa Falls penetrates only to the Kinderhook, so that very little is known of the subsurface geology.

Story County — "The Skunk River anticlinal was first named by McGee (Eleventh Annual Report U. S. Geol. Surv., p. 336 et seq., 1893), because of its trend along the Skunk River (Beyer, Iowa Geol. Surv., Vol. 9, p. 216, 1898). The strike of the fold is presumably northwest-southeast . . . the average dip would be about 35 and 21 feet per mile for the southwest and northeast limbs of the fold respectively." A deep well located at Iowa State College has penetrated the crest of the fold to a depth of 1215 feet, entering the Saint Lawrence beds of the Cambrian. The Saint Louis beds of the Mississippian are at the surface. This structure is thought to have been well tested.

Natural gas wells have been drilled successfully in Story County in the NE¼ SW¼ Sec. 26, Nevada Township. The gas is reported by Beyer (Iowa Geol. Surv., Vol 9, p. 236-8, 1893) to come from a reservoir in the Carboniferous rock at a depth of 90 feet. This is one occurrence of gas in the state which is not from the drift. Whether the reservoir is a separate structure or a part of the Ames anticline is not known. Mr. John B. Hughes of Boone, drilling a well at the corner of Second and Clinton Streets in Boone, encountered gas which caused considerable trouble. The depth is unknown and may have been from the drift.

Norton (Iowa Geol. Surv., Vol. 21, Plate XI, 1910-11) shows the structure at Ames. He states that the Saint Peter at Ames stands 275 feet higher than at Boone, 15 miles farther west. The well is 2,215 feet deep and a record is given by Norton (Iowa Geol. Surv., Vol. 21, pp. 907-8-9-10, 1910-11).

Howell also cites the occurrence of the gas in Story county, but implies the origin in the drift and migration downward to the rock reservoir. (Iowa Geol. Surv., Vol. 29, p. 26, 1920.) He also mentions two other wells which found the same gas flow.

Marshall County — A well was drilled by a local company 1020 feet for gas and coal at Marshalltown. It penetrated 95 feet into the Maquoketa beds.

Boone County — This county has, in the northeastern part, a continuation of the Ames anticline. The gas flow reported under Story county as found at Boone, was probably on the west flank of the Ames structure.

Dallas County — In Dallas county the Redfield anticline is a well-known structure which has been drilled for oil and gas. It lies in the southwestern corner of the county, near the town of Redfield. The axis appears to have a direction approximately north and south. A massive sandstone of the Des Moines forma-

tion is the oldest exposed bed. Judging from the cross section there appears to be another structure in the region of Booneville. The formations are shown rapidly rising to the east from the synclinal axis east of the Redfield anticline. (Leonard, Iowa Geol. Surv., Vol. 8, p. 64, Cross-section I, 1897.)

An interesting item in the log of the Redfield well is that the drill passed through eleven feet of asphaltum at a depth of 1093 feet. (Norton, Iowa Geol. Surv., Vol. 21, p. 826, 1910-11.) The well is on the crest of the anticline and was drilled to a depth of 1384 feet, ending in the Silurian. A low anticline is reported by Leonard (Iowa Geol. Surv., Vol. 8, p. 68, 1897) as lying between De Soto and Van Meter; strike approximately northeast and southwest. The lower beds of the Des Moines formation are at the surface.

Polk County — There are no recorded structures in this county. A drilling for oil and gas was made near Saylorville without results. A record of the drilling is available. (Norton, Iowa Geol. Surv., Vol. 21, p. 898, 1910-11.) It is reported as being 1,800 feet deep and as lying in SE¼ of NE¼, section 12, T 79, N., R. 24 W., Saylor township. (Bain, Iowa Geol. Surv., Vol. 7, p. 410, 1896.)

SOUTH-CENTRAL IOWA

The south-central district embraces the twelve counties of Adair, Appanoose, Clarke, Decatur, Lucas, Madison, Marion, Monroe, Ringgold, Union, Warren and Wayne.

Marion County — In Marion county Miller (Iowa Geol. Surv., Vol. 11, p. 141, 1900) reports the existence of a number of anticlines and synclines of limited extent. Pella is situated near the crest of the largest of these and the Pella beds are at the surface. From the geological map there appears to be a structure located along the Des Moines river in Polk township, where the Saint Louis beds are at the surface. Another point where the Saint Louis beds are exposed is in Lake township along the South Skunk River. This exposure may be a continuation of the Pella anticline. No mention is made in the survey reports of any structures at these points. The appearance of the beds may be due to the uneven erosion surface of the underlying Saint Louis beds, exposed at various elevations, through the Des Moines beds.

A structure in the eastern part of the county is reported by Howell (Iowa Geol. Surv., Vol. 29, Plate IV, 1920) near the town of Harvey. A very slight flexure of the Kinderhook beds

at Pella is shown on the structure section sheet of Norton (Iowa Geol. Surv., Vol. 21, Plate XIII, 1910-11).

Warren County — In Warren county Tilton (Iowa Geol. Surv., Vol. 5, p. 354, 1895) reports the existence of a structure now known as the Ford anticline from its exposure east of the town of Ford in the northeastern part of the county. The structure lies in sections 10, 12, 13, and 24 of Richland township. The axial trend is in a northwest-southeast direction.

Decatur County — Keyes (Iowa Academy of Science, Vol. 23, p. 104, 1916) reports that the "western extension of the Cap-au-Gres fault passes into a fold near Leon, Iowa, which furnishes the most favorable conditions in our state for the occurrence of oil and gas."

Wayne County — In Wayne county two and one-half miles southeast of the town of Seymour a well was drilled for oil and gas. It is reported as having had a showing of oil at 987 feet. This well was abandoned incomplete in March, 1926. The oil showing was thought to be from approximately the same horizon as the Keosauqua oil.

Appanoose County — "At Mystic and Brazil owing to the presence of a marked anticline the coal bearing beds are well exposed." (Bain, Iowa Geol. Surv., Vol. 5, p. 389, 1895).

Another marked structure in Appanoose county is at Numa. Bain (Iowa Geol. Surv., Vol. 5, p. 402, 1895) reports this structure as being a "broad low anticlinal or more probably domelike structure." The Appanoose beds of the Des Moines are at the surface. It is possible that the drilling at Seymour, Wayne County, was located on the southwest flank of the Numa Dome.

This section of the county contains many good structures all of which should be carefully examined. So little work has been done that it is impossible to get from the records the dip or strike or trend of some of these structures.

NORTHWESTERN IOWA

The northwestern district includes nineteen counties — Buena Vista, Calhoun, Carroll, Cherokee, Clay, Crawford, Dickinson, Emmet, Ida, Lyon, Monona, O'Brien, Osceola, Palo Alto, Plymouth, Pocahontas, Sac, Sioux and Woodbury. This part of the state like that lying adjacent to it on the east has very poor records available. No structures are recorded and very little well information is available.

SOUTHWESTERN IOWA

The south-west district includes eleven counties — Adams, Audubon, Cass, Fremont, Harrison, Mills, Montgomery, Page, Pottawattamie, Shelby, and Taylor.

Montgomery County — From the general vertical section as drawn by Lonsdale (Iowa Geol. Surv., Vol. 4, p. 391, Fig. 47, 1894) there is a well defined anticline in Montgomery county, the crest of which lies in the northeastern part of Douglas township near the old Westrope mine. No mention is made of a structure in the report. The Thurman-Wilson fault is shown crossing the county in a northeast-southwest direction. There is a small extension of the Hawleyville anticline into southeastern Montgomery county.

Fremont County — The northwestern part of the county is crossed diagonally by the Thurman-Wilson fault and there is a structure reported as lying on the west flank of the fault. There is an old drill hole near the town of Hamburg 1,000 feet deep drilled by the Hamburg Fuel and Mining Co. in 1890. There is at present a well being drilled which has had showings of oil reported from it at different times, but so far no authentic find has been recorded. During the drilling of the present well a pocket of gas was reported at 1,000 feet. The casing in the well fell 15 feet when the force of the gas had expended itself. The drilling is in charge of Mr. E. P. Hawkins and the geology was worked out by a geologist named McGee.

Howell (Iowa Geol. Surv., Vol. 29, Plate IV, 1920) records an anticlinal structure on the west flank of the Thurman-Wilson fault which extends into southern Mills county. This is the anticline mentioned by Tilton as paralleling the Thurman-Wilson fault (Iowa Geol. Surv., Vol. 27, p. 210, 1916).

Page County — In Page county the Braddyville anticline is reported by Calvin as the most important (Iowa Geol. Surv., Vol. 11, p. 449, 1900). "The axial trend is given as north northeast and south southwest. The axis passes east of the old Shambaugh Mill . . . and in its northward extension passes east of the town of Henshaw in Taylor county. West of the crest of the structure the dip of the coal beds is strongly to the west."

"The limestone exposed in section 36 of Pierce township, near Essex dips rapidly westward and indicates another fold which is probably parallel to the Braddyville anticline" (Calvin, Iowa Geol. Surv., Vol. 11, p. 449, 1900). The Forbes limestone of the Missourian series forms the surface. The prospect hole at Clarinda

is thought to have been favorably located as a test of the structure to the depth of 1,002 feet.

The term Hawleyville anticline is used in connection with this Page county structure by Hager, D. S., (Oil and Gas Journal, p. 110, March 1, 1923).

In Cass county a strong flow of gas is reported from a sandstone at a depth of 184 feet (Tilton, Iowa Geol. Surv., Vol. 27, p. 256, 1916).

Dr. G. S. Smith (Iowa Academy of Science, Vol. 25, p. 521, 1918) states of this part of Iowa, "Instead of having great simplicity in its structure and stratigraphy, there are numerous complications caused by the erratic dips and by the great Jones Point Deformation, and the extent and influence on the local geology of the Brownsville syncline that reaches into Iowa to the southeast corner of Cass county."

Cass County — There seem to be a number of small structures along the Thurman-Wilson fault that have brought the Des Moines stage of the Carboniferous to the surface through the Dakota beds. These exposures are shown on the geologic map by Tilton and lie on the west flank of the fault (Tilton, Iowa Geol. Surv., Vol. 27, p. 276, 1916).

The formation of many of these anticlines is mentioned by Van Tuyl (Iowa Geol. Surv., Vol. 30, p. 349, 1922). "At the close of Ste. Genevieve time the sea withdrew from the upper Mississippi Valley again, and the entire region remained a land area until the close of the Mississippian period. A great warping took place during this emergence, which resulted in a tilting of the Mississippian and earlier formations to the southwest and is known to have been accompanied by the development of small northwest-southeast trending anticlines and synclines, and by extensive brecciation of the hard, brittle St. Louis limestone."

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